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RESEARCH PAPER

Evaluation of Ethiopian Fenugreek (*Trigonella foenum-graecum*) Genotypes against Powdery Mildew (*Erysiphe polygoni*) at Ambo District, West Shewa, Ethiopia

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Abstract

Fenugreek (Trigonella foenum-graecum L) is one of the most important spice crops in Ethiopia. Ethiopia has suitable environmental conditions for fenugreek production and the crop has extraordinary economic importance in the country. However, Powdery mildew caused by Erysiphe polygoni is an economically important disease, especially during the flowering and pod formation stage of the crop and causes significant loss in grain quality as well as quantity. In order to identify resistance materials against the disease, one hundred Ethiopian fenugreek accessions were evaluated. The study was conducted in Ambo district, Bayo Qurbi Farmer's Association Farmers Training Center, during the 2020 main cropping season with alpha lattice design. The study was made under natural epidemic conditions with objectives to identify the source of resistance in Ethiopian Fenugreek materials for further resistance breeding programs and to identify a high-yielding genotype for sustainable production. The study identified two fenugreek genotypes namely 31088 and 237983 showing resistant reactions and 43 genotypes as moderately resistant type. The remaining genotypes showed susceptible reactions. The study also identifies three higher-yielding accessions namely 20428, 35190 and 31087. The results of the study conclude having a crossing program between resistant accessions (31088, 237983) and higher yielding accessions 20428, 35190 and 31087 can result in improved resistance and better yield. The study would be helpful for the development of the breeding program and further improvement of fenugreek crop. Accordingly based on this study genotypes 31088 and 237983 can be used as resistant material for further resistant breeding.

Keywords: Disease resistance, evaluation, fenugreek, powdery mildew

Introduction

Fenugreek (*Trigonella foenum-graecum* L) is an annual plant that belongs to the family Fabaceae (Balodi *et al.,* 1991). Fenugreek is used both as a herb (the leaves) and as a spice (the seed), often called Methi in Urdu/ Hindi/ Nepali). Documented history indicated that it is regarded as the oldest known medicinal plant (Lust, 1986) and has been referred to as a medicinal herb both in Indian Ayurvedic and traditional Chinese medicines (Tiran, 2003). Ancient literature, religious scripture, travel records and anecdotes from different continents and different periods of human history, record a wide variety of medicinal properties associated with fenugreek (Lust, 1986). Medicinal uses vary from wound healing to bust enhancement and, from the promotion of lactation in weaning mothers to its use as a sex stimulant or aphrodisiac (Petropoulos, 2002; Tiran, 2003).

Fenugreek is indigenous to countries on the Eastern shores of the Mediterranean but widely cultivated in India, Argentina, Egypt, Morocco, Southern France, Algeria, Ethiopia, and Lebanon (Kakani *et al*., 2014). Fenugreek was used as a diet both in humans and animals to deliver health benefits. Such diets include dishes with liberal amounts of fenugreek seeds,

which are very popular in southern India (Srinivasan, 2006). Fenugreek hay contains more soluble protein than alfalfa hay, and there is a growing interest in Canada in fenugreek as an alternative feed crop for dairy cows (Acharya *et al*., 2008).

Ethiopia has suitable environmental conditions for fenugreek production and the crop has extraordinary economic importance in the country. It is one of the seed spices, which farmers and private investors in different parts of the country are eager to produce (David, 2002; Birhane, 2012) and is among the major seed spices grown in West Shewa. It is also one of the crops selected for specialization at the national level for their export potential. Currently in Ethiopia, fenugreek covers an area of about 34,603.85 hectares with an average national productivity of about 1.3 t/ha (CSA, 2017). This is less than the attainable yield (1.7 t /ha) under good management practices (CSA, 2017). Despite its extraordinary economic importance, the yield of fenugreek under farmers' conditions is very low (1.28 t/ha). This is much less than the attainable yield under good management practices (5.2 t/ha). The wide yield gap is attributed to the lack of improved varieties for different agroecological zones of Ethiopia, poor agronomic practices, poor soil fertility, diseases (powdery mildew) and insect pests (borer). (Girma *et al*., 2016).

Among many biotic factors that constrained fenugreek production and productivity, the diseases powdery mildew and wilt referred to as the major diseases of the crop mainly cause reduced number of pods per plant, number of seeds per pod and seed weight resulting in significant yield losses up to 40% (Yonas, 2017). Powdery mildew of fenugreek caused by *Oidium* sp. is an important and serious disease, especially during the flowering and pod formation stage of the crop and causes significant yield losses of up to 33.27% as well as grain quality losses (Prakash and Saharan, 2002). The disease was frequently prevalent in fenugreek in the central highlands of Ethiopia with an incidence of about 95% and severity ranges from 20 to 80% (Nigussei *et. al.* 2008). Though powdery mildew is the number one yield constraining disease of the crop, less management effort and less focus is given to the management of the disease in fenugreek.

As host plant resistance is the best and most economical for plant disease management, investigations of resistance genotypes are paramount in breeding for disease resistance. However, the evaluation of fenugreek genotypes in Ethiopia has been an infant and on a small scale. Only some variety of development efforts have been reported from Sinana and Debreziet Agricultural Research Center in the country (DZARC, 2004; SARC, 2005). Consequently, fenugreek takes a considerably low research priority in the national agricultural research system. As the empathy of the other seed spice crops has improved, it is applicable that a more thorough and systematic evaluation of fenugreek genetic resources must be conducted in Ethiopia conditions (Mustefa 2006). Therefore, this study aims to evaluate Ethiopian fenugreek accessions against powdery mildew to identify resistant and high-yielding genotypes for utilization in further breeding programs.

Materials and methods

Description of Study Areas

The study was conducted at Bayo Kurbi Farmers Training Center (FTC) in Ambo district of West Shewa zone of Oromia National Regional State. Ambo district is located at $8^0$56'30'' N latitude and $37^0$47'30''-$37^0$55'15'' E longitude in central Ethiopia, 114 km west of Addis Ababa.

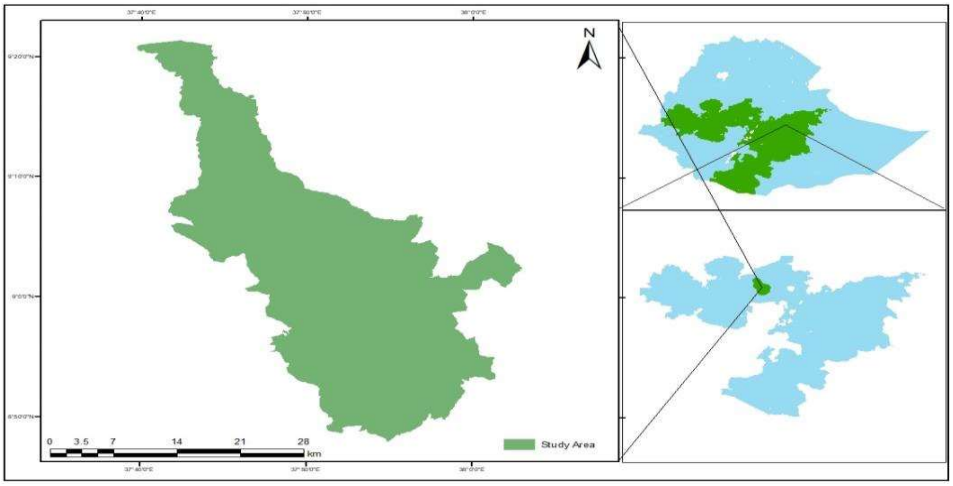

Figure 1: Map of the study area (Source EBI Documentation)

Planting Materials

One hundred fenugreek accessions along with one local check were used for this study. The majority of the accessions represent the national collection from major growing regions of Ethiopia. The materials were obtained from the Ethiopian Biodiversity Institute (EBI), while one local variety was obtained from a local farmer.

Experimental Design

The experimental units were laid out in an alfa lattice design in three replications. The plot size was a single row of 1.5 m long and spacing of 0.30 m between rows and 0.10 m intra-row spacing. A replication holds 4 blocks and contains 100 entries (genotypes) including local checks. Spacing between sub-blocks was 1 m and between the two replications was 1.5 m. Therefore, the total experimental area was 11 m X 30.3 m = 333.3 m^2.

The seed and fertilizer rates were applied as per the national recommendation for the crop. i.e. 25 kg ha-1 of seed, 100 kg ha-1 for NPS and 50 kg ha-1 UREA. Half the rate of Urea and full dose NPS were applied at planting time and the second half rate of Urea was applied at 30 days after emergence immediately after first weeding. The trial was kept weed-free using hand weeding.

Data Collected and Measurements

Disease assessment

Progress of disease development in the plants was observed five times during the epidemiological period. Disease assessments were made by observing the plants that were planted on the plot or row and recorded as diseased and healthy. Disease incidence and severity was taken as a standard procedure (Saxena *et.al.*, 1984).

Disease Incidence (DI): is the number of infected plants over the total number of plants per plot and expressed in percentage. It was calculated by using the following formula.

$$\text{PDI} = \left(\frac{\text{Number of infected plants in the sampling unit}}{\text{Total number of plants in the sampling unit}}\right) \times 100$$

Disease severity (DS) Powdery mildew severities were recorded from 5 randomly tagged plants in a plot starting from the appearance of the disease and then at five-day intervals throughout the season. Disease scoring was done based on the percent leaf area infected with a 0–9 rating scale (Saxena *et.al.*, 1984). 0= No disease, 1= 0–3 Few small leaf lesions, 2= 3–6 Few lesions on few leaves with no stem lesions, 3= 6–12 Few lesions on few leaves or with superficial stem lesions, 4= 12–25 Few well-formed leaf lesions or superficial stem lesions, 5= 25–50 Few well-formed leaf

lesions or enlarging stem lesions, 6= 50–75 Many large leaf lesions or deep stem lesions with abundant sporulation or plant more than 50% defoliated, 7= 75–87 Many large coalescing leaf or stem lesions, over 75% of plant area affected or defoliated, 8= 87–100 Plants largely defoliated, leaf or stem with abundant sporulating lesions and 9= 100% Plants dead.

The severity scores were converted into percent severity index (PSI) for analysis using the following formula:

$$\text{PSI} = \frac{\text{Sum of numerical ratings } x \text{ 100}}{\text{No. of plants scored } x \text{ Maximum score of the scale}}$$

The disease severity indexes obtained from different assessment periods were used to calculate the Area under the Disease Progress Curve (AUDPC-%day) of the recording period. The area under the disease progress curve (AUDPC) was calculated for each genotype. AUDPC-% day is used to quantify and summarize the severity of the disease over time. AUDPC was calculated from the severity data following the formula by Saxena *et.al.* (1984).

$$\text{AUDPC} = \sum_{i=1}^{n-1} 0.5(Xi + Xi+1)(ti+1 - ti)$$

Whereas: AUDPC = area under disease progress curve, n is the total number of assessment times, t_i is the time of the i^{th} assessment in days from the first assessment date, x_i is the percentage of disease severity at i^{th} assessment. The sum total of disease progress during the different assessment periods was used as the final AUDPC-%day at the end of the epidemiological period. AUDPC-%day values were then used in different analysis packages in the study to compare the amount of disease among plots with different genotypes.

After analysis of the disease parameters (PDI, PSI and AUDPC) the genotypes in the population were categorized into five categories namely resistant (0–10%), moderately resistant (11–20%), moderately susceptible (21–40%), susceptible (41–60%) and highly susceptible (>60%) based on the PSI value.

Phonological Parameter

Days of emergence: recorded as the number of days from planting to at which 50% of the plants in the experimental unit emerge or germinate.

Days to 50% flowering: was recorded as the number of days from planting to 50% flowering of a row

Days to 95% physiological maturity: was recorded as the number of days from planting to 95% full maturation/physiological maturity in an experimental unit.

Grain filling period (GFP):- was calculated as the difference between days to maturity and days to flowering (DM-DF).

Yield and Yield Components

Plant height (PH) in cm: - An average height of plants at 90% physiological maturity was measured from the ground level to the tip of the main stem.

Number of branches per plant: taken average number of primary branches (branches from the main stem) from five plant randomly sampled plants.

Number of nodes per plant (NNPPl): - was determined as the average number of nodes from the five sampled plants per plot.

Number of pods per plant (NPPPl):- was determined as an average of pods counted from five randomly selected plants per plot.

Pod length (PL) in cm: the average length of pods measured in cm from five randomly sampled plants per plot

Above Ground Biomass (AGBM) (ton/ha): The weight of yield total biomass per plot was measured after harvest sun dry and converted to ton/ha.

Number of seeds per pod (NSPP): the average number of seeds counted from total pods from five randomly sampled plants per plot.

Hundred seed weight (HSW) (g):- Hundred seeds were counted from each plot and the weight was taken using electronic balance and adjusted at 12% moisture content.

Seed yield per plant (SYPPl) (g):- was recorded as the average weight of seeds from five randomly sampled plants and adjusted at 12% moisture content.

Seed yield per hectare (SYPH) (ton/ha): The weight of yield of seeds per plot was measured and adjusted at 12% content and converted to ton/ha.

Harvest index (HI):- was calculated by dividing grain yield per plot by total above-ground dry biomass yield per plot and multiplied by hundred.

$$HI = \frac{\text{Grain Yield}}{\text{BiomassYield}} x100$$

Data Analysis

Analysis of variance (ANOVA) was made using SAS version 9.2 (SAS, 2008). When ANOVA indicates significant differences among treatment means. Mean comparisons were carried out using the least significant difference (LSD) at a 5% level of significance. Correlation analysis was made to analyze the relation of the disease parameters to yield parameters. And principal component analysis was made to group the genotypes.

Results and discussions

Disease Development and Genotype Reaction

The result of the screening indicated that the evaluated genotypes fall into four disease reaction classes namely resistant, moderately susceptible, susceptible and highly susceptible. Of the hundred genotypes evaluated two genotypes namely 237983 and 31088 exhibited resistance reactions against the powdery mildew pathogen with the mean disease severity of 9.49 and 7.19, respectively (Table 1). Similarly, forty-three of the genotypes showed moderate resistance, fifty-four were susceptible and one genotype showed highly susceptible disease reaction with mean disease severity of 69.92 (Table 1). The study revealed that there was disease reaction variation among Ethiopian fenugreek landraces. Different scholars also found that there is a variation among fenugreek genotypes in reaction to powdery mildew pathogen. According to Prakash and Saharan (1999) amongst 44 lines screened against powdery mildew, GC-39 and UM-32 were found free from fungal infection, whereas GC-7, GC-20, and UM-34 were categorized as resistant varieties.

The current results indicated that there were high variations in disease development between the resistant and susceptible genotypes which reveals resistant genotypes potentially reduce the disease incidence and severity than the susceptible genotypes (Table 1). This finding is in agreement with the finding of Raje *et.al.* (2003) who reported that there was a heavy incidence of powdery mildew in susceptible check while less incidence in resistance material.

In the current study, apart from powdery mildew, other fenugreek disease was recorded during the field experiment, including Cercospora leaf spot and rust in cropping seasons. Although these diseases occurred prior to powdery mildew in cropping season it was at very low intensity. With regard to insect pests, in cropping seasons the major insect pests that occurred during the experiment included Cutworm (*Agrotis ipsilon*), damaging them near the ground in the seedling stage and leaf miners were found to severely damage the Fenugreek plants soon after flowering and pod formation.

Table 1. Reaction of fenugreek genotypes against powdery mildew (*Erysiphe polipolygoni*) under field condition

S/N	Genotypes/ Accessesion	Percent disease severity	Host plant reaction	S/N	Genotypes/ Accessesion	Percent disease severity	Host plant reaction
1	234032	40.41	S	51	9239	36.75	MS
2	235133	55.92	S	52	31087	40.39	S
3	237983	9.49	R	53	28601	23.52	MS
4	31088	7.19	R	54	31100	32.17	MS
5	28506	46.45	S	55	53078	57.92	S
6	230880	36.54	MS	56	215820	43.01	S
7	239070	40.02	S	57	221732	43.35	S
8	215731	37.75	MS	58	28599	54.44	S
9	238247	50.91	S	59	Check	37.68	MS
10	19906	34.44	MS	60	212877	48.35	S
11	28603	23.47	MS	61	28607	30.46	MS
12	18754	31.9	MS	62	28615	49.22	S
13	28613	41.81	S	63	20429	51.56	S
14	237511	36.7	MS	64	28605	56.16	S
15	20430	31.13	MS	65	53010	56.71	S
16	28612	39.65	MS	66	53008	53.27	S
17	18835	43.73	S	67	19908	42.46	S
18	231320	69.92	HS	68	239061	55.53	S
19	53096	54.67	S	69	239067	53.7	S
20	31085	42.49	S	70	212658	50.3	S
21	220020	44.35	S	71	29561	36.65	MS
22	35194	29.87	MS	72	28602	52.36	S
23	237982	44.89	S	73	230673	59.25	S
24	19903	34.8	MS	74	28604	53.89	S
25	20428	22.99	MS	75	28598	40.17	S
26	19902	24.86	MS	76	29563	56.32	S
27	28600	52.92	S	77	28606	49.88	S
28	220022	31.24	MS	78	19907	53.26	S
29	28596	28.76	MS	79	212775	37.08	MS
30	220024	25.14	MS	80	220023	47.7	S
31	29560	33.08	MS	81	35191	50.3	S
32	29564	36.28	MS	82	53021	44.93	S
33	53097	33.45	MS	83	18840	41.99	S
34	220025	29.34	MS	84	28614	36.18	MS
35	18834	25.15	MS	85	212777	51.16	S
36	31091	32.65	MS	86	53018	52.56	S
37	230536	24.87	MS	87	15331	39.94	MS

Table 1: continued

S/	Genotypes/	Percent	Host	S/	Genotypes/	Percent	Host plant
38	216899	50.52	S	88	19905	48.09	S
39	28610	38.51	MS	89	230674	36.23	MS
40	234034	33.54	MS	90	17732	45.65	S
41	53016	59.93	S	91	53062	54.93	S

42	53072	52.76	S	92	28609	40.68	MS
43	9563	37.21	MS	93	28608	47.79	S
44	53014	44.12	S	94	19904	36.05	MS
45	35190	30.62	MS	95	237985	36.32	MS
46	53009	35.48	MS	96	236621	55.31	S
47	53061	34.76	MS	97	53064	55.6	S
48	18822	32.8	MS	98	31102	43.72	S
49	53080	35.36	MS	99	28611	56.09	S
50	53089	47.15	S	10	28505	44.96	S

R= Resistant, MS= moderately susceptible, S= susceptible HS= highly susceptible

Analysis of variance (ANOVA) results for agronomic and disease parameters also revealed that different fenugreek genotypes responded differently to the infection of powdery mildew. The results showed AUDPC and all agronomic parameters except plant height (PH) and number of primary branches per plant (NPBPPl) were significantly different among tested genotypes (Table 2, 3 & 4). The analysis of variance showed that there is no significant difference among genotypes concerning plant height (PH) and number of primary branches per plant. This might be related to the late coming of the pathogen at which the plant grows to its optimum height and primary branch and the two traits were similar in fenugreek genotypes. Typical powdery mildew symptoms of infection were observed beginning from sixty-two (62) days post-germination. The symptoms began from the lowest leaf among the plants. The powdery mildew appeared as small white powdery spots on the lower and upper surfaces of the leaves. The powdery mildew progresses to other leaves as the plants grow. These were observed virtually on all the leaves of the plants. Gupta *et al*. (1997) screened 110 lines of fenugreek for resistance to Erysiphe polygoni, Rhizoctonia solani and Fusarium oxysporum in Hisar (Haryana). None of the genotypes was completely resistant to all three pathogens. However, GP 75, GP 82, GP 94, GP and PEB were the moderately resistant lines and lines are significantly different in the yield and yield component parameters.

Table 2. Reaction of fenugreek germplasm for phenological parameters under powdery mildew disease (*Erysiphe polygoni*) under field conditions

ENTRY	**ACC**	**Phonological parameters**			
		DE	DF	DM	GFP
1	234032	6.33bcde	49.00	132.67	83.67
2	235133	6.33bcde	45.67	132.00	86.33
3	237983	6.33bcde	49.33	131.33	82.00
4	31088	6.00cd-e	47.33	131.67	84.33
5	28506	6.67ab-e	47.00	134.33	87.33
6	230880	6.00cde	47.67	132.00	84.33
7	239070	6.67ab-e	44.33	131.00	86.67
8	215731	7.33abc	45.33	132.00	86.67
9	238247	5.33e	47.00	131.33	84.33
10	19906	7.33abc	46.33	132.33	86.00
11	28603	6.33bcde	47.00	131.67	84.67
12	18754	6.33bcde	49.00	133.67	84.67
13	28613	5.67de	46.33	132.33	86.00
14	237511	6.33bcde	48.00	134.67	86.67

15	20430	6.33bc-e	47.33	131.33	84.00
16	28612	6.33bc-e	47.00	132.67	85.67
17	18835	7.00abcd	45.67	132.00	86.33
18	231320	6.00cde	46.33	132.67	86.33
19	53096	7.00abcd	47.00	134.67	87.67
20	31085	6.00cde	48.67	134.67	86.00
21	220020	6.33bcde	46.67	133.00	86.33
22	35194	7.00abcd	45.67	130.33	84.67
23	237982	7.67ab	45.33	131.00	85.67
24	19903	7.67ab	46.00	130.67	84.67
25	20428	6.33bcde	47.33	132.33	85.00
26	19902	7.33abc	47.00	131.00	84.00
27	28600	7.33abc	46.33	132.00	85.67
28	220022	7.00abcd	49.00	134.33	85.33
29	28596	6.67ab-e	47.33	131.33	84.00
30	220024	5.67de	47.00	133.00	86.00
31	29560	6.67ab-e	45.67	131.00	85.33
32	29564	6.33bcde	48.33	133.00	84.67
33	53097	6.00cde	49.33	132.00	82.67
34	220025	7.00abcd	47.00	132.67	85.67
35	18834	7.33abc	46.00	131.67	85.67
36	31091	7.00abcd	47.67	133.00	85.33
37	230536	6.67ab-e	47.67	135.33	87.67
ENTRY	**ACC**	**Phonological parameters**			
		DE	DF	DM	GFP
38	216899	6.33	46.00	134.00	88.00
39	28610	6.33	47.33	132.33	85.00
40	234034	7.33	45.00	130.67	85.67
41	53016	6.00	46.67	132.67	86.00
42	53072	7.67	46.33	131.00	84.67
43	9563	7.33	46.00	131.33	85.33
44	53014	6.33	47.00	132.00	85.00
45	35190	7.33	46.33	132.67	86.33
46	53009	5.33	47.00	132.00	85.00
47	53061	7.00	45.33	132.67	87.33
48	18822	6.33	48.00	133.00	85.00
49	53080	7.33	47.67	131.33	83.67
50	53089	5.67	49.00	132.67	83.67
51	9239	7.00	46.00	131.00	85.00
52	31087	6.67	48.00	132.67	84.67
53	28601	7.33	46.67	132.33	85.67
54	31100	7.67	46.00	131.00	85.00
55	53078	6.33	47.00	131.67	84.67
56	215820	6.00	48.33	131.67	83.33
57	221732	6.00	46.00	131.67	85.67
58	28599	6.67	46.67	131.33	84.67
59	Check	6.67	47.67	132.33	84.67
60	212877	6.67	46.33	131.00	84.67
61	28607	7.33	46.67	130.67	84.00
62	28615	6.00	46.00	131.00	85.00
63	20429	6.33	46.67	132.67	86.00
64	28605	6.00	46.00	131.67	85.67

65	53010	6.33	47.67	133.00	85.33
66	53008	7.00	46.00	130.33	84.33
67	19908	7.00	47.33	131.33	84.00
68	239061	6.00	45.33	133.67	88.33
69	239067	6.67	46.67	131.67	85.00
70	212658	7.67	46.67	131.00	84.33
71	29561	6.33	48.00	132.33	84.33
72	28602	6.67	46.67	132.00	85.33
73	230673	6.33	47.67	132.00	84.33
74	28604	6.33	48.00	134.00	86.00
ENTRY	**ACC**	**Phonological parameters**			
		DE	DF	DM	GFP
75	28598	6.00	49.00	133.33	84.33
76	29563	5.67	47.33	132.67	85.33
77	28606	5.67	48.67	133.00	84.33
78	19907	7.00	47.33	131.00	83.67
79	212775	7.33	46.33	131.00	84.67
80	220023	7.00	47.00	131.67	84.67
81	35191	7.33	47.00	131.00	84.00
82	53021	7.33	46.67	131.00	84.33
83	18840	7.00	46.67	130.67	84.00
84	28614	8.00	45.00	130.67	85.67
85	212777	7.67	45.67	131.67	86.00
86	53018	7.00	45.00	133.00	88.00
87	15331	6.67	46.00	133.67	87.67
88	19905	7.00	45.67	135.67	90.00
89	230674	6.67	47.00	132.00	85.00
90	17732	6.67	44.67	133.33	88.67
91	53062	7.00	46.33	131.67	85.33
92	28609	6.33	48.33	135.33	87.00
93	28608	6.33	47.33	132.00	84.67
94	19904	6.33	47.00	134.33	87.33
95	237985	5.67	46.67	132.33	85.67
96	236621	6.33	48.33	134.00	85.67
97	53064	7.33	46.00	131.33	85.33
98	31102	7.67	45.33	130.67	85.33
99	28611	7.00	47.67	134.33	86.67
100	28505	8.00	45.33	130.00	84.67
min		5.33	44.33	130.00	82.00
max		8.00	49.33	135.67	90.00
mean		6.67	46.86	132.24	85.38
Cv		13.33	3.06	0.95	1.90
LSD		1.4315	2.3097	2.029	2.6094
P value		0.03	0.0031	<0.0001	0.02

DE= Days of emergence, DF= Days to 50% flowering, DM=Days to maturity, GFP=Grain filling pried

* = significant at $p<0.05$, ** =significant at $p<0.001$ and *** = significant at $p< 0.0001$

Table 3. Reaction of fenugreek germplasm for growth parameters under powdery mildew disease (*Erysiphe polygoni*) under field conditions

ENTRY	ACC	Growth parameters				
		PL	NPBPPl	NSBPPl	NNPPl	NPPPl
1	234032	8.33	3.20	0.67	15.80	3.53
2	235133	9.40	3.67	2.67	29.60	12.47
3	237983	7.53	3.10	2.00	26.20	8.33
4	31088	7.93	4.63	1.67	25.87	9.07
5	28506	9.23	3.93	2.00	33.60	14.00
6	230880	8.00	4.13	0.67	28.30	11.87
7	239070	8.33	3.40	2.33	29.93	9.33
8	215731	8.53	3.40	2.00	31.70	11.77
9	238247	8.97	4.33	2.60	25.93	10.80
10	19906	8.43	5.40	2.00	28.07	9.60
11	28603	8.30	4.00	1.00	29.87	11.53
12	18754	7.83	3.67	2.00	18.67	6.93
13	28613	8.70	3.37	1.67	30.40	7.73
14	237511	8.90	4.40	2.33	30.07	9.27
15	20430	7.17	4.47	1.60	13.33	3.20
16	28612	8.33	4.77	1.67	32.00	12.60
17	18835	9.23	5.07	2.33	32.87	11.80
18	231320	7.97	4.07	1.67	29.13	8.53
19	53096	8.27	4.07	1.67	32.40	13.17
20	31085	8.30	4.33	0.67	27.73	10.53
21	220020	7.77	3.73	2.00	24.60	9.67
22	35194	7.70	3.77	2.33	35.07	12.47
23	237982	8.70	3.87	1.00	37.47	15.73
24	19903	7.60	4.23	2.33	35.83	11.80
25	20428	9.33	3.93	1.87	29.53	12.00
26	19902	7.07	4.07	1.13	24.80	8.53
27	28600	7.93	4.37	1.67	28.37	11.07
28	220022	7.53	4.03	1.47	23.53	10.33
29	28596	8.57	4.17	1.33	30.83	11.43
30	220024	9.20	3.57	1.33	28.47	10.33
31	29560	7.73	3.47	1.00	21.13	7.33
32	29564	7.33	4.33	2.33	29.80	11.87
33	53097	8.07	3.87	1.73	23.37	8.47
34	220025	8.53	3.90	2.13	19.10	6.53
35	18834	9.33	3.90	3.00	25.87	9.80
36	31091	7.77	5.33	2.00	28.47	10.53
37	230536	8.07	3.67	1.67	30.73	9.93
38	216899	8.53	4.03	2.67	35.27	14.00
39	28610	7.33	4.67	2.27	17.53	6.73
40	234034	8.50	3.77	2.33	29.50	10.40
41	53016	7.93	3.93	2.00	31.93	12.13
42	53072	8.07	4.00	2.33	31.07	10.53
43	9563	8.17	4.40	1.93	30.53	12.53
44	53014	8.53	3.73	2.00	32.77	13.10
45	35190	7.80	4.33	1.40	36.00	13.67
46	53009	8.70	3.80	2.33	34.40	13.47
47	53061	7.47	3.47	2.47	27.07	12.00
48	18822	8.03	4.03	2.30	30.70	9.67

49	53080	9.17	4.00	2.00	34.53	12.60
50	53089	7.97	4.07	2.00	24.60	8.73
51	9239	8.50	3.93	2.67	25.80	7.80
52	31087	9.33	3.80	2.33	29.13	10.17
53	28601	7.43	4.60	2.07	27.87	9.20
54	31100	7.17	4.80	3.00	25.47	12.00
55	53078	9.63	4.03	2.33	30.80	12.00
56	215820	8.63	4.80	2.33	24.93	8.87
57	221732	7.87	3.20	1.00	25.73	7.13
58	28599	8.03	3.70	2.33	29.97	11.13
59	Check	9.00	4.43	1.80	27.13	9.87
60	212877	7.87	4.40	0.87	24.53	8.07
61	28607	8.97	3.40	1.27	27.93	9.33
62	28615	7.90	5.00	2.00	26.07	9.53
63	20429	8.17	3.77	1.00	20.20	6.87
64	28605	7.43	4.00	2.67	23.57	8.60
65	53010	7.67	4.10	1.67	26.13	11.60
66	53008	7.50	3.70	2.33	16.60	7.17
67	19908	8.13	3.57	2.33	24.33	10.63
68	239061	8.50	4.53	2.00	24.93	12.47
69	239067	8.40	4.30	2.00	29.20	8.87
70	212658	8.07	4.23	0.93	24.13	9.27
71	29561	7.87	3.47	2.67	26.53	9.27
72	28602	8.37	3.70	1.93	25.73	9.73
73	230673	9.53	4.30	2.33	33.87	12.93
74	28604	8.20	4.90	2.33	33.53	13.63
75	28598	9.03	4.47	2.33	32.87	12.73
76	29563	8.30	3.93	1.87	28.13	10.87
77	28606	8.30	4.00	1.67	27.00	10.33
78	19907	9.33	3.73	2.33	31.13	11.97
79	212775	7.80	3.57	2.67	24.10	8.33
80	220023	9.17	3.93	2.33	26.80	8.67
81	35191	7.40	4.27	2.83	26.33	9.07
82	53021	7.67	4.20	0.47	25.20	10.60
83	18840	6.47	3.60	2.67	31.27	9.37
84	28614	8.20	4.20	2.67	29.40	9.13
85	212777	8.17	3.27	1.73	26.13	9.80
86	53018	8.00	3.87	2.00	32.47	12.47
87	15331	8.33	4.80	2.00	22.47	8.60
88	19905	7.17	3.13	1.67	28.93	8.47
89	230674	7.53	3.80	1.67	22.67	8.47
90	17732	9.63	3.33	2.33	32.40	12.60
91	53062	8.33	4.07	1.67	13.07	3.13
92	28609	8.53	3.53	1.67	33.87	13.00
93	28608	9.07	3.90	1.33	27.40	11.40
94	19904	8.67	4.20	1.67	19.47	6.87
95	237985	8.30	4.73	1.67	27.93	10.60
96	236621	7.70	3.80	2.00	34.07	8.47
97	53064	8.47	3.77	1.67	34.40	11.07
98	31102	8.90	4.73	3.00	41.00	12.07
99	28611	9.53	3.43	2.67	33.13	12.67
100	28505	9.43	3.60	2.00	37.40	11.33

min	6.47	3.10	0.47	13.07	3.13
max	9.63	5.40	3.00	41.00	15.73
mean	8.27	4.03	1.94	28.05	10.20
Cv	6.5	11.63	5.45	18.89	26.2
LSD	0.8669	4.4565	0.3534	4.3123	0.5914
P value	<0.0001	0.55	<0.0001	<0.0001	<0.0001

PL= Pod length, NPBPP= number of primary branches, NSBPP= Number of secondary branches, NNPPl =Number of nodes per plant, NPPPl= Number of pods per plant

* = significant at p<0.05, ** =significant at p<0.001 and *** = significant at p< 0.0001 and ns=non-significant

Table 4. Reaction of fenugreek germplasm for AUDPC, yield and yield component parameters under powdery mildew disease (*Erysiphe polygoni*) under field conditions

ENTRY	**ACC**	**Yield and disease parameters**						
		NSPP	SYPPl	HSW	SYPH	AGBM	HI	rAUDPC
1	234032	7.80	0.23	1.13	0.71	18.67	16.944	44.44
2	235133	8.60	0.36	1.43	1.53	37.00	19.785	54.35
3	237983	3.93	0.14	0.83	0.42	8.33	23.452	7.69
4	31088	5.40	0.19	0.97	0.66	11.67	24.688	5.46
5	28506	8.67	0.29	1.30	1.39	39.00	16.551	48.98
6	230880	6.73	0.22	1.20	0.87	22.33	18.978	33.98
7	239070	7.80	0.27	1.33	1.50	36.00	18.406	37.5
8	215731	7.47	0.24	1.23	1.34	28.67	20.105	37.96
9	238247	6.00	0.31	1.33	1.66	28.67	25.205	50.09
10	19906	7.47	0.30	1.50	1.23	29.33	17.991	34.44
11	28603	8.27	0.30	1.80	1.44	27.33	24.159	25.09
12	18754	8.40	0.37	1.63	1.44	46.67	14.56	36.11
13	28613	6.80	0.28	1.47	0.77	24.67	13.675	37.69
14	237511	8.27	0.41	1.53	1.86	37.33	22.714	38.24
15	20430	6.80	0.14	1.33	0.76	25.00	13.45	30.65
16	28612	8.00	0.23	1.40	1.01	35.00	14.226	38.98
17	18835	7.93	0.30	1.33	1.36	28.33	21.735	44.07
18	231320	7.00	0.38	1.50	1.91	35.33	24.003	69.26
19	53096	6.93	0.27	1.13	1.39	29.00	21.156	59.91
20	31085	6.93	0.33	1.23	1.45	30.00	19.681	45.46
21	220020	7.33	0.20	1.30	0.81	20.67	19.967	47.22
22	35194	6.87	0.32	1.30	1.44	22.33	29.076	33.33
23	237982	5.93	0.21	1.27	1.13	20.33	25.614	42.69
24	19903	7.13	0.33	1.07	1.27	24.00	23.345	31.48
25	20428	6.87	0.26	0.93	1.00	23.33	19.151	21.76
26	19902	6.27	0.24	0.83	0.73	14.67	19.358	26.57
27	28600	7.73	0.25	1.17	1.46	19.00	30.285	54.63
28	220022	8.20	0.25	1.37	1.22	21.00	26.383	30.46
29	28596	6.13	0.34	1.23	1.56	26.00	25.172	26.85
30	220024	6.00	0.17	1.10	0.74	18.67	18.826	21.94
31	29560	7.20	0.33	1.17	1.46	31.67	22.458	31.39
32	29564	5.27	0.21	1.23	1.04	16.33	29.778	33.06
33	53097	5.53	0.23	1.20	0.87	17.33	23.022	30.65
34	220025	5.20	0.19	1.17	0.79	16.33	22.814	26.3
35	18834	7.33	0.13	1.30	0.81	19.00	19.02	28.61
36	31091	5.40	0.28	1.03	0.86	17.33	22.441	34.54

37	230536	7.73	0.32	1.13	1.26	27.00	21.894	27.41
38	216899	7.73	0.25	1.37	1.46	29.67	22.374	53.06
39	28610	6.13	0.27	1.40	1.39	24.67	21.718	41.48
40	234034	6.67	0.28	1.20	1.17	24.67	21.515	30.56
41	53016	7.13	0.23	1.17	0.87	26.33	14.885	63.43
42	53072	7.07	0.22	1.17	1.28	23.33	24.188	49.44
43	9563	6.53	0.23	1.17	1.16	25.33	22.415	34.07
44	53014	6.40	0.19	1.20	0.87	17.00	23.206	42.59
45	35190	7.20	0.40	1.60	1.99	35.67	24.111	30.83
46	53009	8.80	0.35	1.43	1.53	38.33	19.095	33.24
47	53061	8.47	0.32	1.50	1.67	32.33	23.278	36.39
48	18822	10.53	0.35	1.63	1.70	49.00	14.097	37.5
49	53080	9.07	0.40	1.30	1.45	40.67	17.512	32.13
50	53089	6.80	0.27	1.37	0.74	27.33	13.232	46.67
51	9239	8.20	0.26	1.43	0.99	26.67	16.956	36.76
52	31087	9.27	0.41	1.50	2.18	47.67	19.632	38.33
53	28601	7.07	0.26	1.53	1.26	29.33	19.226	25.19
54	31100	6.93	0.14	1.27	0.76	26.33	13.076	36.2
55	53078	7.87	0.39	1.57	1.56	34.67	21.48	57.59
56	215820	6.87	0.18	0.87	0.93	22.33	18.405	41.02
57	221732	9.53	0.40	1.47	1.94	43.67	20.062	42.04
58	28599	8.60	0.32	1.37	1.45	37.67	15.67	52.13
59	Check	8.07	0.31	1.20	1.16	31.67	16.19	34.63
60	212877	6.87	0.20	1.30	0.59	22.00	11.821	46.67
61	28607	6.73	0.21	1.03	0.70	18.00	17.672	28.15
62	28615	5.87	0.26	1.00	1.08	24.00	15.174	45.09
63	20429	7.80	0.28	1.40	1.56	34.67	18.587	48.43
64	28605	7.93	0.26	1.17	1.07	24.33	20.47	54.63
65	53010	8.20	0.22	1.43	1.09	34.67	13.542	59.54
66	53008	8.13	0.27	1.37	1.48	26.67	23.976	55.65
67	19908	6.27	0.20	0.87	0.66	14.33	23.409	39.81
68	239061	8.47	0.33	1.40	1.53	43.33	16.294	61.85
69	239067	7.93	0.27	1.40	1.35	28.00	23.532	52.5
70	212658	7.47	0.19	1.17	1.15	26.00	18.874	48.43
71	29561	6.60	0.14	1.47	0.65	26.67	12.236	34.63
72	28602	5.80	0.25	1.50	1.13	26.67	16.682	55.37
73	230673	7.40	0.28	1.30	1.19	31.67	17.655	56.02
74	28604	8.13	0.35	1.10	1.14	35.33	15.091	55.19
75	28598	7.60	0.19	1.23	0.73	22.00	14.909	42.96
76	29563	6.60	0.33	1.03	0.92	15.67	26.207	52.69
77	28606	7.07	0.12	0.80	0.33	21.33	7.022	56.2
78	19907	5.60	0.21	1.03	0.53	16.67	15.076	50.74
79	212775	5.13	0.19	1.30	0.56	16.33	15.569	34.07
80	220023	6.07	0.12	1.13	0.40	15.00	12.741	46.39
81	35191	5.40	0.22	0.77	0.77	15.67	16.913	52.69
82	53021	6.47	0.23	0.97	0.84	18.67	18.56	41.94
83	18840	7.00	0.33	1.20	1.20	28.33	18.097	41.67
84	28614	5.40	0.17	1.20	0.70	17.33	18.294	35.19
85	212777	6.13	0.28	1.20	1.21	23.33	22.284	54.17
86	53018	8.40	0.22	1.27	1.26	27.67	19.495	53.89
87	15331	7.20	0.15	1.27	0.72	24.67	12.965	47.5
88	19905	7.27	0.26	1.03	0.76	18.67	17.471	48.43
89	230674	6.73	0.17	1.03	0.75	21.33	15.201	38.61

90	17732	8.07	0.29	1.30	1.27	29.67	20.074	47.31
91	53062	6.67	0.12	1.37	0.63	19.33	15.536	53.24
92	28609	8.20	0.17	1.00	0.53	20.33	11.132	47.04
93	28608	7.40	0.26	1.27	1.14	29.67	17.197	48.33
94	19904	8.07	0.27	1.07	1.17	25.67	21.119	42.41
95	237985	8.40	0.36	1.37	1.93	41.00	19.075	34.26
96	236621	6.67	0.26	1.33	0.79	20.67	19.424	56.85
97	53064	8.13	0.31	1.50	1.91	38.33	19.993	52.41
98	31102	8.27	0.40	1.40	1.76	34.67	22.003	41.48
99	28611	9.13	0.18	1.23	0.87	39.00	10.354	56.39
100	28505	7.93	0.32	1.53	1.41	34.00	18.769	40.65
min		3.93	0.12	0.77	0.33	8.33	7.02	5.46
max		10.53	0.41	1.80	2.18	49.00	30.29	69.26
mean		7.23	0.26	1.26	1.14	26.83	19.22	41.75
Cv		9.42	17.48	18.97	50.98	35.09	34.27	31.75
LSD		4.2638	0.0737	0.384	0.9372	15.144	10.615	21.394
P value		<0.0001	<0.000	<0.00	0.02	<0.0001	0.08	<0.0001

NSPP = number of seed per plant, SYPPl= Seed yield per plant, HSW=Hundred seeds weight in gram, SYPH = Seed yield per hector, AGBM = Above ground biomass, HI= Harvest index, and rAUDPC= residual Area under disease progress curve

* = significant at p<0.05, ** =significant at p<0.001 and *** = significant at p< 0.0001 and ns=non-significant

Correlation Analysis

The Pearson's correlation coefficients between possible pairs of agronomic traits and disease parameters tested using SAS software (SAS, 2009). The results showed that correlation among most of the yield and yield components in fenugreek are positive and significant (Table 5). Seed yield per hector (SYPH) had positive and significant correlations with all paired yield component traits except pod length. The result revealed that genotypes with better (longer) in grain filling period are better in their seed yield and the plants bearing more number of nodes per plant, more number of pods per plant and more number of seeds per pod produce more seed yield. Indeed genotypes with better hundred seed weight had higher above ground biomass and seed yield per hector. Thus, selection for better yield component traits will bring about a definite improvement in above ground biomass and seed yield. The trait (SYPH) is non-significant with disease parameters, area under disease progress curve (AUDPC) and disease progress rate (DPR) (Table 5). The disease parameters AUDPC and disease progress rate were non- significant with most yield component parameters except grain filling period and number of seed per pod. This result revealed that the pathogen mainly affect the phonological development of the genotypes and finally affect the number of seeds per plot. Generally, this study revealed that resistant genotypes were significantly reducing the disease parameters (Table 1 & 5) but low yielder. This phenomenon happened in non-elite resistant material because they mobilize most of their genetic resource for disease response than yield response. This indicate that as powdery mildew is a series disease in fenugreek and the resistant genetic materials identified in this study are important for cross breeding with elite high yielding genotypes.

Table 5. Correlation between different agronomic traits of fenugreek genotypes and their final disease reaction to powdery mildew disease

	GFP	PL	NNPPl	NPPPl	NSPP	SYPPl	HSW	AGBM	HI	rAUDPC	PDR
PL	0.106ns										
NNPPl	0.211*	0.353**									
NPPPl	0.237*	0.348**	0.820**								
NSPP	0.356**	0.253*	0.205*	0.188ns							
SYPPl	0.168ns	0.137ns	0.342**	0.213*	0.511**						
HSW	0.193ns	0.135ns	0.107ns	0.033ns	0.515**	0.480**					
AGBM	0.274**	0.249*	0.237*	0.217*	0.799**	0.695**	0.665**				
HI	0.000ns	-0.107ns	0.143ns	0.156	-0.183	0.331**	0.037ns	-0.181ns			
rAUDPC	0.314**	0.112ns	0.070ns	0.134ns	0.277**	0.092ns	0.115ns	0.254*	-0.218*		
PDR	0.325**	0.096ns	0.033ns	0.094ns	0.281**	0.098ns	0.066ns	0.228*	-0.177	0.644**	
SYPH	0.257*	0.131ns	0.286**	0.245*	0.577**	0.842**	0.607**	0.773**	0.426**	0.137ns	0.146ns

GFP =Grain Filling Pried, PL=Pod Length, NNPPl =Number of Nod Per Plant, NPPPl =Number of Pod Per Plant, SYPPl =Seed Yield Per Plant, HSW=Hundred seeds weight,
AGBM = Above ground biomass, HI= Harvest index, rAUDPC= residual Area Under Disease Progress Curve, PDR=Percent Disease Reduction and SYPH = Seed yield per hector

Key: *=significant @ p<0.05; **=significant @ P,0.01; ns=non-significant

Cluster Analysis

Hierarchal clustering of the average linkage method with squared Euclidian distance were performed using MINITAB14 software (MINITAB (2003). The distances between clusters were calculated using average linkage method of squared Euclidian distance. The average linkage Euclidian distance technique of clustering produced a more understandable portrayal of the 100 fenugreek accessions by grouping them into six clusters, whereby different members within a cluster is being assumed to be more closely related in terms of the trait under consideration with each other than those members in different clusters. Similarly, members in clusters with non-significant distance were assumed to have more close relationship with each other than they are with those in significantly distant clusters. In this study the hundred genotypes were grouped in to five clusters. Among the five clusters maximum inter cluster distance (ED=9.642) was found between cluster 3 and cluster 6 indicating possibility of inter crossing the genotype of the two clusters. On the other hand minimum inter cluster distance (3.700) was recorded between cluster 2 an 4 indicating their genetic relatedness. The highest intra clusters some of square (947.379) was recorded in cluster 2 which consists of 74 genotypes.

Table 6. Clusters of 100 fenugreek genotypes in to different diversity classes

Clusters of 100 fenugreek genotypes									
Cluster-1	Cluster-2					Cluster-3	Cluster-4	Cluster-5	Cluster-6
G1	G2	G7	G74	G75	G35	G3	G12	G23	G88
G15	G55	G8	G56	G33	G84		G14	G97	
G39	G73	G40	G62	G50	G78		G95	G100	
G91	G58	G86	G11	G71	G80		G48	G98	
G64	G69	G72	G45	G6	G77		G52		
G66	G59	G85	G22	G60	G81		G49		
G34	G93	G24	G83	G70	G20		G18		
G87	G65	G27	G45	G82	G37		G68		
G94	G13	G42	G25	G26	G28		G31		
	G46	G43	G30	G67	G92		G51		
	G93	G47	G32	G89	G99		G63		
	G5	G10	G96	G61	G54				
	G38	G17	G41	G21	G4				
	G19	G16	G44	G51	G9				
	G90	G36	G76	G79					

G= Genotype

Cluster 1: It consisted of 9 genotypes which were collected from Oromia and Amhara regions. Members in this cluster laid on intermediate value in all the traits under consideration.

Cluster 2: It consisted of 74 genotypes, which were early in days to flowering, intermediate in biomass yield, number of pods and seeds per plant and number of seeds per pod. Among these clusters the genotype /accession, 35190 is high yielder. Accessions in this cluster also exhibited lower with hundred seed weight, seed yield per plant harvest index and 1 accessions exhibited resistant and the remaining exhibited moderately susceptible as well as susceptible to powdery mildew disease.

Cluster 3: It consisted of 1 genotype characterized by late in days to flowering; low in seed and biomass yield and number of seeds and pods per plant high in hundred seed weight. It also exhibited intermediate, number of seeds per pod harvest index and resistant to powdery mildew disease.

Cluster 4: It had 11 genotypes which exhibited early growth periods, short days to flowering; low in hundred seed weight and intermediate in both biomass yield and number of pods per plant. Among these clusters the accession, 237985 exhibited intermediate seed yield per plant, seeds per pods, harvest index and resistant to powdery mildew disease.

Cluster 5: It consisted of four genotypes. The accessions under this category were relatively inferior in most of the traits investigated. It was characterized by intermediate days to flowering; exhibited lowest in all traits under studied except hundred seed weight, harvest index and moderately susceptible to powdery mildew.

Cluster 6: It consisted of one genotype from Tigrai. It was found to be the most superior accession regarding the traits studied. This accession was characterized by low in hundred seed weight and harvest index. However, this particular accession also required longer period to maturity, characterized by intermediate seed and biomass yield per plant, number of seeds and pods per plant and seeds per pod and moderately susceptible response to powdery mildew. In general, the differences between the clusters were mainly attributed to the variation in all traits. Other traits such as days to flowering, biomass yield and number of seeds per plant have contributed equally well for cluster constellations.

Table 7: Mean and range of genetic diversity in disease resistance and seed traits of the hundred clusters of *T. foenum-graecum*

Characters	Clusters													
	1			**2**			**3**	**4**			**5**			**6**
	Min	Max	Mean	Min	Max	Mean	Mean	Min	Max	Mean	Min	Max	Mean	Mean
DE	5.8	7	6.5	5.2	7.9	6.7	6.3	5.5	7.3	6.4	7.2	8.1	7.6	7.1
DF	45.8	48.6	46.8	44.5	49.6	46.9	49.5	44.9	48.9	47	45.2	46.1	45.5	45.9
DM	130.2	134.1	132.5	130.1	135.2	132.2	131.6	131.2	134.5	132.7	130.1	131.6	130.9	135.4
GFP	84.3	87.7	85.8	82.6	88.4	85.3	82.1	83.9	88.2	85.7	84.8	85.8	85.4	89.5
NPBPPl	3.2	4.8	4	3.2	5.4	4	3.1	3.5	4.7	4	3.6	4.7	4	3.2
NSBPPl	0.7	2.5	1.8	0.6	3	2	2	1.1	2.5	2	1	2.9	1.9	1.7
NPPPl	15.6	33.5	20.3	18.4	35.2	28.7	27.8	21	33	27.4	34.4	39	36.9	7.1
NSPP	5.5	8.8	7.4	5.1	9.2	7	4.7	7.2	10	8.4	6.5	8.8	8	27.7
NNPPl	5.1	12.8	7.6	7.7	14.5	10.5	12	9.1	11.1	10.2	9.5	14.8	11.6	7.2
PL	7.4	8.7	8.2	6.5	9.6	8.3	7.7	7.9	9.3	8.5	8.6	9.5	8.9	7
AGBM	15.7	38.6	24.6	11	41.8	25.4	9.9	24.8	47.3	38.9	23.8	42.2	34.4	18.3
SYPPl	0.1	0.3	0.2	0.1	0.4	0.3	0.1	0.2	0.4	0.4	0.2	0.4	0.3	0.3
SYPH	0.6	1.8	1.1	0.1	2	1.1	0.5	0.9	2.1	1.6	1.2	2	1.6	0.7
HSW	1	1.5	1.3	0.7	1.8	1.2	0.9	1.2	1.7	1.5	1.3	1.5	1.4	1
rAUDPC	29.3	56.2	44.3	7.2	59.9	41.7	9.5	31.9	69.9	40.9	43.7	55.6	47.3	48.1
Disease reaction class	MS to S			R to S			R	MS to HS			S			S

DE= Days of emergence, DF= Days to 50% flowering, DM=Days to maturity, GFP=Grain filling pried, PL= Pod length, NPBPP= number of primary branch, NSBPP= Number of secondary branch, NNPPl =Number of nodes per plant, NPPPl= Number of pods per plant,AGBM=Above ground Biomass, N SPPL=Number of seeds per plant, NSPP=Number of seeds per pod, SYPH= Seed yield per hector, HSW=Hundred seeds weight in gram, SYPPL=Seed yield in g per plant, AUDPC=Area under disease progress curve.

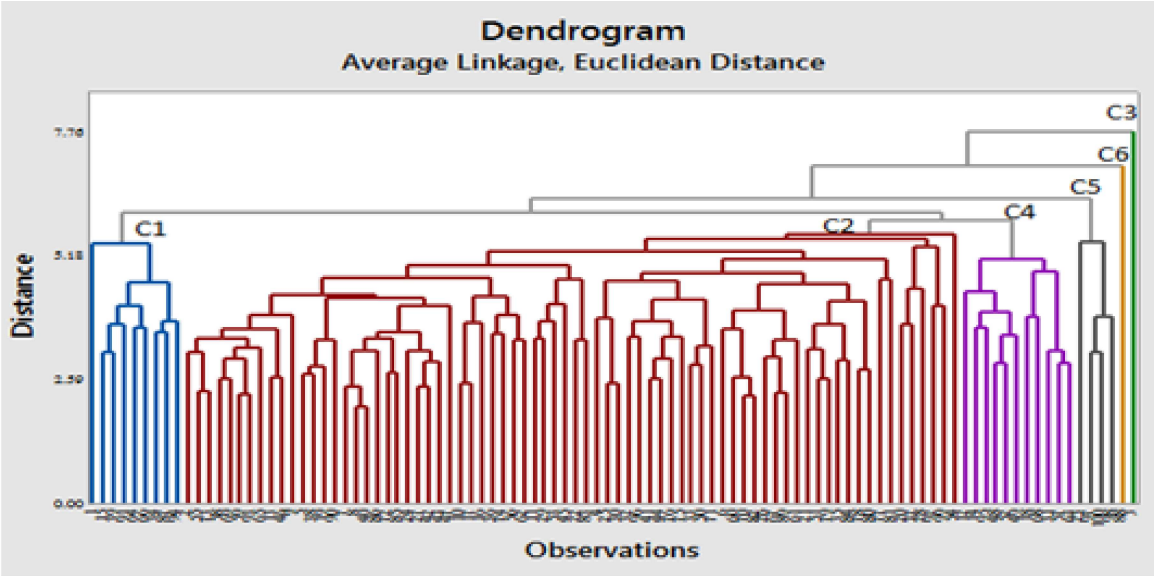

Figure2: Figurative indicators of Dendrogram Average linkage, Euclidean Distance between six clustering of 100 Fenugreek Genotypes

Conclusion and recommendation

Fenugreek (*Trigonella foenum-graecum L.*) is one of the most important seed spice crops in Ethiopia. West showa zone Ambo district is among the major fenugreek producing areas in Ethiopia. Despite its importance, this crop is low yielding due to multiple biotic and abiotic factors. Powdery mildew caused by Erysiphe polygoni is the most economically important disease of the crop in this area. The result of the current study reveals the disease is prevalent with high incidence and severity on susceptible genotypes. According to the result of the current study two fenugreek genotypes viz. 31088 and 237983 show resistant reaction which could cross with 35190 and 31087 which are relatively high yielder. The two resistant accessions also have intermediate performance in their agronomic response and so can be used for development of powdery mildew resistant fenugreek genotypes without fear of losing agronomic performance. Thus, those materials viz. 31088 and 237983 found resistant to powdery mildew disease can be used as germplasm to broaden the genetic base of fenugreek for sustainable production in the country. However, further evaluation of the materials under optimum disease pressure including evaluation of the materials under greenhouse condition is needed.

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Conflicts of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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